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RESPONSE OF WESTERN LARCH TO CHANGES IN STAND DENSITY AND STRUCTURE

by

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ABSTRACT

The 5-year growth response of a 55-year-old, even-aged western larch stand thinned from above and from below to a wide range of stocking levels was measured in eastern Oregon. Both basal area and volume growth increased as stand density increased for both thinning methods. Diameter growth increased moderately in response to decreasing stand density when thinned from above and from below, but height growth was not affected by thinning intensity or method.

Thinning from above does not appear to be a sound silvicultural practice in previously unmanaged larch stands of this age because the intermediate and suppressed trees with small crowns are unable to respond to the additional growing space. And, because of mortality caused by windthrow and exposure, net volume growth is significantly less than in plots thinned from below.

Keywords: *Western larch,* Larix occidentalis, *thinnings(-stand volume, stand structure, stand density.*

As forest management is intensified in the mixed-conifer forest of eastern Oregon, information is needed on growth and yield of managed stands so managers can formulate stocking level regimes to meet their objectives. Results from thinning studies provide some of the basic data on which control of stocking level is based.

Although some information is available on the response of western larch (*Larix occidentalis* Nutt.) to thinning from studies in Montana and British Columbia (Roe and Schmidt 1965, Illingworth 1964, Thompson 1969), little is known about the growth of managed larch stands in eastern Oregon. Seidel (1971) reported on the effects of thinning on a 33-year-old larch stand in northeastern Oregon, but additional studies are needed.

In 1970, a study was begun in an even-aged larch stand in northeastern Oregon. The purpose of this study was

to obtain data on growth of larch after thinning to several density levels and by two thinning methods. This paper reports results from the first 5-year period of the study.[1]

STUDY AREA AND METHODS

The study is located on Boise-Cascade land about 6 miles (9.7 km) northwest of Elgin, Oregon, on a gentle east-facing slope at an elevation of about 3,000 feet (914 m). The stand was 55 years old when first thinned in 1970 and has a site index of about 83 feet (25 m) at age 50.[2] The soil is classified as a Tolo silt loam, which is a well-drained Regosol developed from dacite pumicite originating from the eruption of Mount Mazama (Crater Lake) 6,500 years ago. It is underlain at a depth of about 4 feet (1.2 m) by a buried soil developed from basalt.

The larch stand on the study area is a seral stage of an *Abies grandis/ Pachistima myrsinites* plant community (Franklin and Dyrness 1973). Many genera of shrubs and herbs such as *Thalictrum, Symphoricarpos, Smilacina, Trifolium, Spiraea, Vicia, Rosa, Fragaria, Osmorhiza,* and *Anemone* are found on the study area. Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco), grand fir (*Abies grandis* (Dougl.) Lindl.), and Engelmann spruce (*Picea engelmannii* Parry) are also present.

The study consists of a 4 by 2 factorial randomized block design replicated two times for a total of sixteen 0.286-acre (0.116-ha) plots. The first factor is density and consists of four levels: 50, 90, 130, and 170 ft^2 of basal area per acre (11.5, 20.7, 29.8, and 39.0 m^2 per hectare). The second factor is thinning method; these are: above (cutting largest trees--dominants and codominants) and below (cutting smallest trees--suppressed, intermediate, and smaller codominants). Analyses of variance were used to test significance of treatment effects, and regression analyses related diameter, basal area, and volume growth to residual basal area.

All plots were well stocked before treatment, ranging from 191 to 226 ft^2 of basal area per acre (43.8 to 51.9 m^2 per hectare) (table 1). Trees were spaced from 8.5 to 10.3 feet (2.6 to 3.1 m) apart, and average d.b.h. ranged from 8.2 to 9.8 inches (20.8 to 24.9 cm). All plots after thinning from above contained 2 to 8 percent of Douglas-fir, grand fir, or Engelmann spruce except one plot where 22 percent of the residual basal area was grand fir and Douglas-fir. All trees in plots thinned from below were larch.

Plots were thinned with a Drott "feller-buncher."[3] This machine utilizes shears and a grapple mounted on a 25-foot (7.6-m) boom with a crawler tractor undercarriage. Operation of this equipment required prior removal of all trees (clearcut) in swaths 20 feet (6.1 m) wide. Swaths were spaced 50 feet (15.2 m) apart and oriented east and west through the stand (fig. 1). The "feller-buncher" then moved along these clearcut strips, reaching 25 feet (7.6 m) into the thinning strips to cut and remove the entire tree. Some variation in residual stocking levels between replications and between thinning methods for a given density level existed because a few trees marked for cutting were missed and some leave trees were accidentally pushed over by the "feller-buncher."

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[1] A cooperative research effort between the Boise-Cascade Corporation and the Pacific Northwest Forest and Range Experiment Station.

[2] Site index based on curves in "Ecology and Silviculture of Western Larch Forests," by Wyman C. Schmidt, Raymond C. Shearer, and Arthur L. Roe, U.S. Department of Agriculture Tech. Bull., in preparation for publication.

[3] Mention of product name does not imply endorsement by the U.S. Department of Agriculture over other machines that can do the work.

Table 1--*Stand characteristics per acre of western larch before and after 1970 thinning and 5 years later*[1]

Density level	Basal area	Number of trees	Average spacing	Quadratic mean diameter	Average height[2]	Volume[3] Total	Volume[3] Merchantable, including ingrowth
	Square feet		Feet	Inches	Feet	Cubic feet	Board feet
Before initial (1970) thinning:							
Thinned from above							
1 (lowest)	221.5	420	10.2	9.8	85.1	7,177	26,816
2	191.5	495	9.4	8.4	80.3	6,032	18,540
3	213.7	408	10.3	9.8	90.1	6,883	27,020
4 (highest)	202.0	513	9.2	8.5	82.0	6,285	18,045
Thinned from below							
1	211.0	490	9.4	8.9	95.3	6,892	24,555
2	205.5	557	8.8	8.2	91.8	6,688	20,898
3	221.5	596	8.5	8.3	93.7	7,192	19,479
4	226.0	525	9.1	8.9	92.4	7,402	26,446
After thinning:[4]							
From above							
1	50.6	133	18.1	8.4	85.1	1,647	2,816
2	93.8	257	13.0	8.2	80.3	2,906	5,687
3	126.0	231	13.7	10.0	90.1	4,091	13,990
4	153.0	400	10.4	8.4	82.0	4,670	10,054
From below							
1	48.9	58	27.4	12.4	94.8	1,686	8,331
2	87.7	114	19.5	11.9	91.8	2,974	13,503
3	131.8	196	14.9	11.1	93.7	4,448	16,790
4	169.0	219	14.1	11.9	92.0	5,801	24,440
1975:[4]							
Thinned from above							
1	50.4	111	19.8	9.1	88.3	1,668	4,309
2	99.2	239	13.5	8.7	84.0	3,105	7,273
3	132.9	220	14.1	10.5	94.5	4,346	15,880
4	158.2	378	10.7	8.8	86.0	4,876	13,260
Thinned from below							
1	55.5	58	27.4	13.3	99.1	1,925	10,005
2	96.5	114	19.5	12.5	95.1	3,312	16,141
3	141.4	196	14.9	11.5	96.9	4,775	19,732
4	183.6	219	14.1	12.4	96.4	6,274	28,440

[1]Based on plots without clearcut strips.
[2]Average height of trees measured with dendrometer (about 15 per plot).
[3]Total cubic-foot volume--entire stem, inside bark, all trees. Board-foot volume, International 1/4-inch rule--trees 10.0-inch d.b.h. and larger to a 6-inch top d.i.b.
[4]Basal area, number of trees, and volume per acre after thinning and in 1975 should be reduced by 29 percent if clearcut strips are included in plot area.

Figure 1.--Aerial view of part of the thinned area showing alternating thinned and clearcut strips.

Diameters of all plot trees were measured to the nearest one-tenth inch (0.25 cm) in 1970 and 1974. In addition, about 15 trees covering the range of diameters were measured with an optical dendrometer in 1970 and 1974 to calculate an equation expressing volume of the entire stem inside bark as a function of diameter for each plot. The volume equations developed from the 1970 measurements were used to compute plot volumes (cubic feet and board feet, International 1/4-inch rule) at the beginning and end of the period. Height growth was measured by dendrometer on trees chosen for volume equation measurements.

Because of the mechanized thinning equipment used in this stand, much of the total area was occupied by clearcut strips, resulting in a reduction in volume growth compared with a thinned area completely occupied by trees. Therefore, in this paper, growth per acre is presented in two ways: based on the 0.286-acre (0.116-ha) plot completely occupied by trees and based on a larger 0.4-acre (0.162-ha) plot that includes the clearcut strips.

Examination of basal area and volume growth data for the plot containing 22-percent basal area in fir revealed an unusually high growth rate because of the more rapid growth of the fir. Therefore, data from this plot were not used in the growth analyses.

RESULTS

Diameter Growth

Diameter growth per tree was greatest on the most heavily thinned plots for both thinning methods (table 2). The average growth in plots thinned from above declined from 0.1 inch (0.25 cm) per year at the lowest density level to 0.05 inch (0.13 cm) per year at the highest density. In plots thinned from below, growth slowed from 0.16 to 0.09 inch (0.41 to 0.23 cm) per year as stocking increased. Diameter growth in plots thinned from below was significantly greater ($P < 0.05$) than growth in plots thinned from above (fig. 2), and a significant ($P < 0.01$) linear relationship existed between diameter growth and residual basal area for both thinning methods. There was no significant interaction between thinning method and density levels.

Diameter growth of the 49 largest trees per acre (121/ha) was somewhat greater than growth of all trees (table 2), and differences were more apparent in plots thinned from above and at higher density levels because of more smaller, slower growing trees in these plots. Although there was a tendency for larger trees to grow slightly faster than smaller trees, there was little relationship between diameter and diameter growth during the 5 years. Regressions of diameter growth on initial diameter for each plot resulted in r^2 values ranging from 0.03 to 0.52. Many small trees had no measurable increment, but a few 6-inch (15-cm) trees grew as well as some 15-inch (38-cm) trees. On the other hand, not all large trees grew rapidly. One 22-inch (56-cm) tree and several 14- and 15-inch (36- and 38-cm) trees added no measurable growth.

As one might expect, thinning method had a considerable effect on the diameter distribution and stand structure of plots. Thinning changed the diameter of the average tree (tree of average basal area) as follows:

Thinning method and density level	Change in average diameter
(Ft^2 per acre)	(Inches)
Above:	
50	-1.4
90	-.2
130	0
170	-.1
Below:	
50	+3.5
90	+3.7
130	+2.8
170	+3.0

Table 2--*Periodic annual growth and mortality per acre of western larch after initial thinning at age 55*

Density level	All trees													49 largest trees--diameter growth[1]
	Residual basal area	Diameter growth[1]	Basal area growth			Total volume growth			Merchantable volume growth, including ingrowth			Board-foot ingrowth		
			Net	Mortality	Gross	Net	Mortality	Gross	Net	Mortality	Gross			
	Square feet	Inches	- - - Square feet - - -			- - Cubic feet - -			- - - Board feet - - -			Board feet	Percent	Inches
Based on area without clearcut strips:														
Thinned from above														
1 (lowest)	51	0.10	-0.04	1.12	1.08	4	34	38	299	0	299	225	75.2	0.12
2	94	.08	1.08	.85	1.93	40	25	65	317	0	317	163	51.4	.12
3	126	.08	1.38	1.12	2.50	51	37	88	378	132	510	202	39.6	.14
4 (highest)	153	.05	1.04	.91	1.95	41	24	65	641	0	641	456	71.2	.09
Thinned from below														
1	49	.16	1.32	0	1.32	48	0	48	335	0	335	33	9.8	.17
2	88	.12	1.76	0	1.76	68	0	68	528	0	528	109	20.6	.13
3	132	.08	1.92	0	1.92	65	0	65	588	0	588	278	47.2	.10
4	169	.09	2.92	0	2.92	95	0	95	800	0	800	248	31.0	.12
Based on area including clearcut strips:														
Thinned from above														
1	36	.10	-.03	.81	.78	3	24	27	213	0	213	161	75.6	.12
2	67	.08	.78	.61	1.39	29	18	47	227	0	227	116	49.8	.12
3	89	.08	.98	.80	1.78	36	26	62	268	94	362	143	39.6	.14
4	109	.05	.74	.65	1.39	29	18	47	458	0	458	326	71.2	.09
Thinned from below														
1	35	.16	.94	0	.94	34	0	34	239	0	239	24	10.0	.17
2	63	.12	1.25	0	1.25	48	0	48	377	0	377	78	20.7	.13
3	94	.08	1.36	0	1.36	47	0	47	420	0	420	198	47.1	.10
4	121	.09	2.07	0	2.07	68	0	68	571	0	571	177	31.0	.12

[1]Arithmetic diameter growth of trees living through the 5-year period.

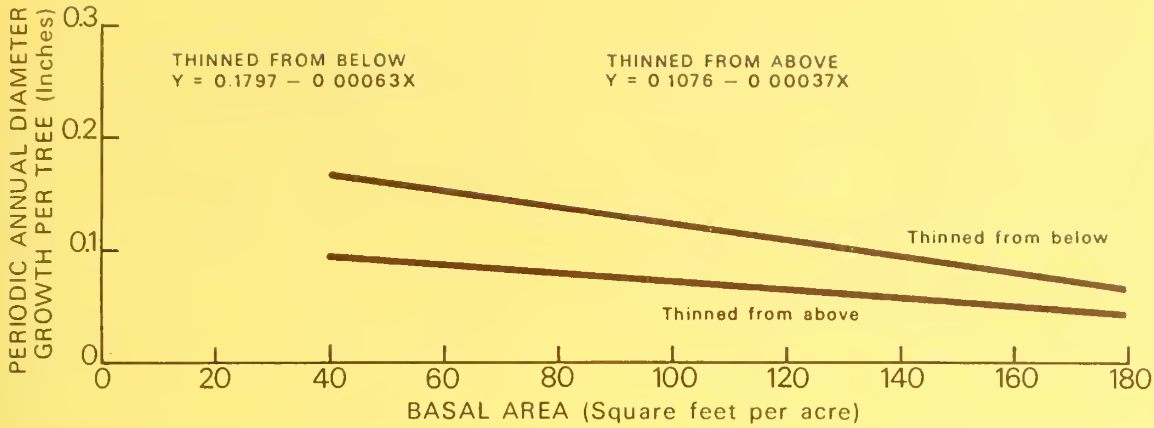

Figure 2.--Periodic annual diameter growth by density level and thinning method, 1970-75.

Diameter increment was much greater for firs and spruce than for larch. On the one plot containing 22-percent basal area in fir, fir grew 0.18 inch (0.46 cm) and larch 0.06 inch (0.15 cm) per year. Most of the fir in this plot were in the intermediate to suppressed crown classes before thinning. Because of their shade tolerance, however, they had relatively full crowns and thus were able to respond quickly to the increased growing space provided by thinning.

Height Growth

Height growth was insensitive to thinning method or changes in stand density (fig. 3). Only insignificant differences in growth occurred as stocking changed within a thinning method, and there was no significant growth difference between thinning methods. Increment ranged from 0.62 to 0.88 feet (0.19 to 0.27 m) per year in plots thinned from above and from 0.62 to 0.89 feet (0.19 to 0.27 m) per year in plots thinned from below.

As in the case of diameter growth, there was a poor relationship between height growth and height at time of thinning (r^2 values from 0.03 to 0.34).

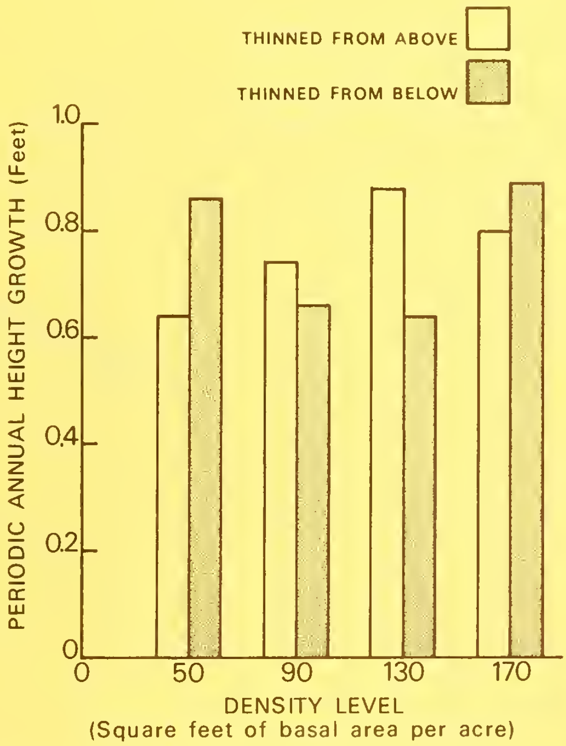

Figure 3.--Periodic annual height growth by density level and thinning method, 1970-75.

Mortality and Damage

All the mortality occurred in plots thinned from above. Of the 570 trees in these plots, 40 died; but there was no noticeable effect of density level on mortality. Death is attributed to either windthrow or shock following release. Most of the trees that died were in the intermediate and suppressed crown classes and thus had not developed sufficient windfirmness or large enough crowns to keep pace with the increased respiratory rate after release.

In addition to mortality losses, 53 study trees (all but 5 in the plots thinned from above) were leaning at angles estimated to be 10 to 35 degrees from the vertical as a result of wind or ice damage.

Basal Area Growth

Basal area increment showed an upward trend for both thinning methods as stocking increased (table 2). There was no significant difference in gross basal area growth between the two thinning methods. But because of the mortality in plots thinned from above, net basal area growth was significantly greater ($P < 0.05$) in plots thinned from below (fig. 4). The regressions of both gross and net basal area growth on stand density were linear ($P < 0.05$), and no significant interaction was found between thinning method and stand density.

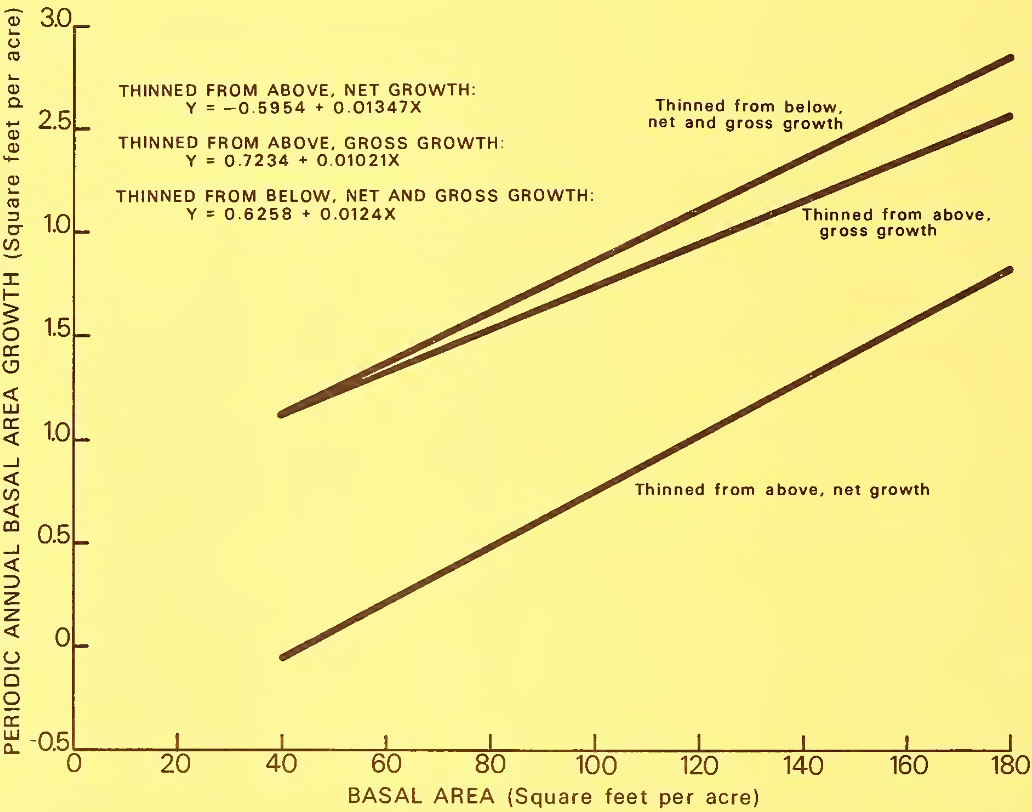

Figure 4.--Periodic annual basal area growth by density level and thinning method, 1970-75. Only one curve for plots thinned from below is shown because net and gross growth are equal because of no mortality.

Volume Growth

Cubic volume increment responded to changes in stand density in the same manner as basal area increment--growth increasing as density became greater. Comparison of cubic volume increment between the two thinning methods indicates that plots thinned from below grew significantly better than those thinned from above both in net ($P < 0.01$) and gross ($P < 0.05$) growth (fig. 5). Mortality caused a loss of from 37 to 89 percent of the gross cubic volume growth in plots thinned from above in contrast to no loss in plots thinned from below.

Analyses of both net and gross cubic volume growth in figure 5 indicated that the data do not depart significantly from linearity. However, over a greater range of stand densities, a curvilinear relationship is more likely since growth must necessarily be zero at zero stand density and will tend to level off and then decline as stocking increases above 180 ft^2 of basal area per acre (41 m^2/ha). Although volume increment is greater at high stand densities, the volume is distributed over a large number of trees, many of which are smaller and slow growing. Thinning serves to transfer growth to fewer faster growing trees in addition to utilizing potential mortality. For example, in plots thinned from below, 58 trees per acre (143/ha) at the low density level produced 51 percent of the cubic volume grown by 219 trees per acre (541/ha) at the high level; in plots thinned from above, gross growth on 133 trees per acre (329/ha) was 58 percent of that on 400 trees per acre (988/ha).

Net board-foot volume increment was impressive during the period, ranging from 299 to 641 board feet per acre annually on the plots thinned from above and from 335 to 800 board feet per acre per year on plots thinned from below (table 2). There was no loss of board-foot increment to mortality except for one 14-inch (36-cm) tree that blew down in level 3 (thinned from above); thus gross growth is essentially the same as net. One-tenth to three-fourths of the board-foot increment consisted of ingrowth which is the volume of trees periodically growing into measurable size.

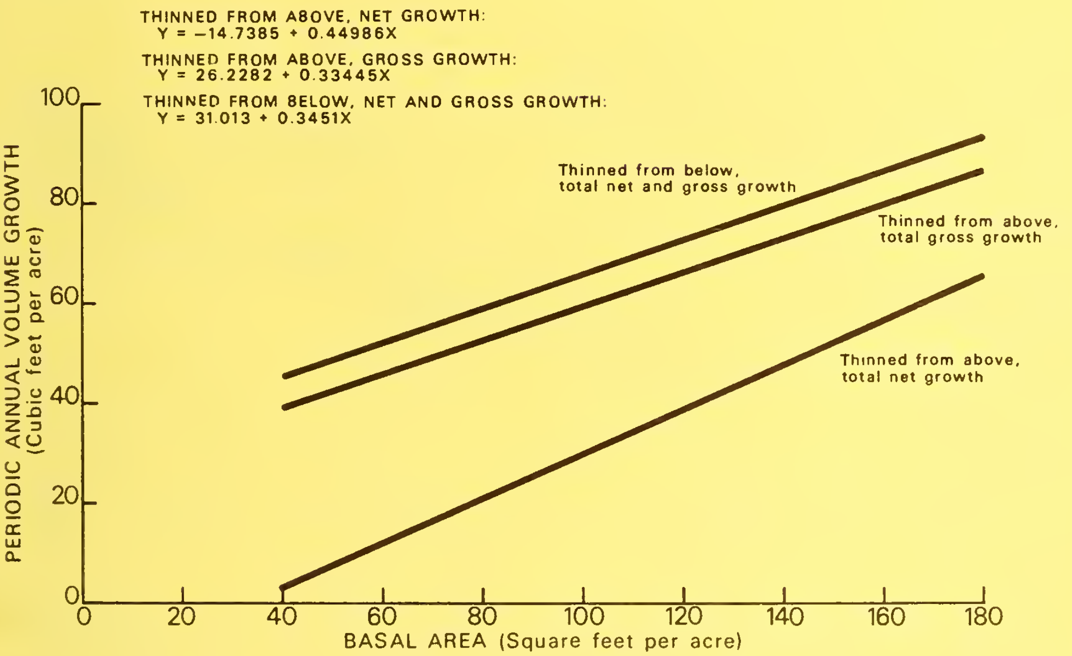

Figure 5.--Periodic annual cubic volume growth by density level and thinning method, 1970-75. Only one curve for plots thinned from below is shown because net and gross growth are equal because of no mortality.

Similar to cubic volume growth, net board-foot increment of plots thinned from below was significantly greater ($P < 0.05$) than net increment of plots thinned from above (fig. 6), and the difference between gross board-foot growth for the two thinning methods was almost significant at the 5-percent level. A significant ($P < 0.01$) linear relationship was found between board-foot growth and stocking level over the range of densities used.

Thinning this stand with the "feller-buncher" caused about 29 percent of the total area to be occupied by clearcut strips, with a corresponding 29-percent reduction in volume growth compared with a thinned area completely occupied by trees. This percentage reduction in volume growth is equal to that proportion of the area not occupied by trees because of the 29-percent difference in the per-acre conversion factors used for the two plot sizes. Because of root and crown expansion into the clearcut strips as the stand grows older, the actual reduction in volume growth on an area basis should be less than the 29 percent calculated. The growth and mortality data on an area which includes the clearcut strips are shown in the bottom half of table 2.

DISCUSSION

It is not possible to generalize in regard to thinning prescriptions for western larch stands from isolated studies. However, after only 5 years of growth, some trends seem apparent. Thinning from above does not appear to be a sound silvicultural practice in previously unmanaged larch stands of this age. Because of the shade intolerance of larch, crowns of the smaller trees in the stand are reduced in size and thus are unable to immediately use the increased growing space. The reduction in net volume growth because of mortality of smaller trees is another disadvantage of thinning from above. Additional mortality of trees already damaged by wind and snow could result in stocking levels too low for efficient site utilization and in continued low growth rates.

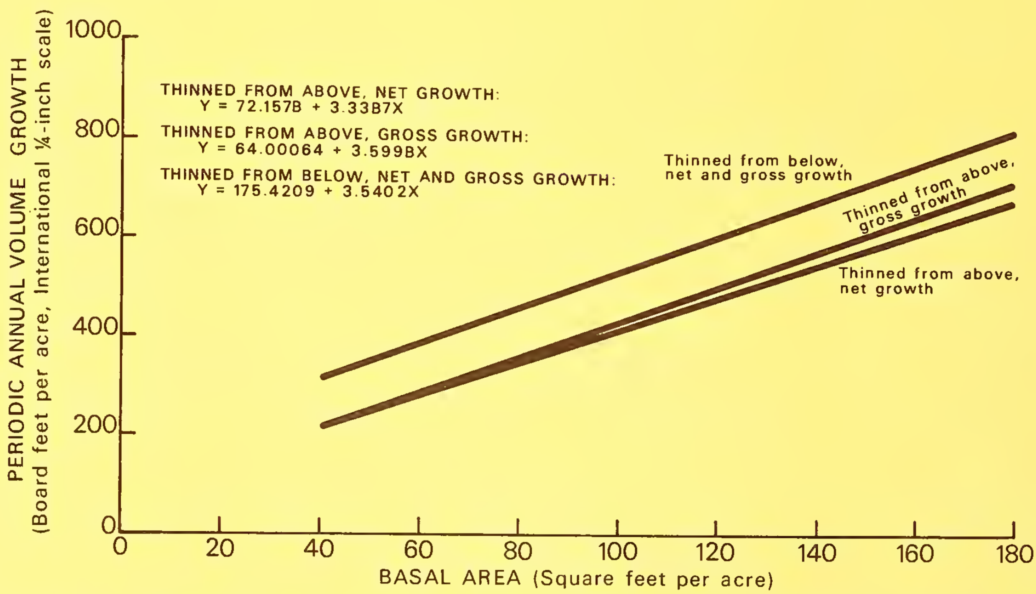

Figure 6.--Periodic annual board-foot (International 1/4-inch rule) volume growth by density level and thinning method, 1970-75. Only one curve for plots thinned from below is shown because net and gross growth are equal because of no mortality.

For thinning from below in stands such as this one, what is the proper residual stocking level? Obviously, there is no single best stand density; but the answer depends on the objectives of thinning in terms of timber management as well as the relative importance to the land manager of other uses of the forest such as range, wildlife, water yields, or recreation. Some objectives of thinning for timber management purposes are: (1) to stimulate diameter growth rate of residual trees so merchantable products may be harvested sooner and rotations shortened, (2) to salvage volume that otherwise would be lost through mortality, and (3) to obtain the maximum volume growth per acre that is consistent with other objectives.

In this study, from 70 to 100 percent of the trees left on the plots thinned from below were 10-inch (25-cm) d.b.h. or larger. In such a stand, near-maximum diameter growth to reach merchantability limits quickly is no longer the prime objective. Rather, thinning goals now are to utilize mortality, to maintain good volume growth per acre, or to shorten rotations. If the management objective is to obtain high volume growth per acre, then a light thinning from below is indicated to utilize anticipated mortality. If, on the other hand, the aim is to shorten the rotation--with a sacrifice of some volume growth--a heavier thinning is suggested.

Although 55 years old, about 63 percent of the trees in this stand were less than 10-inch (25-cm) d.b.h. before thinning. Obviously, a thinning program begun at an earlier age would have transferred the rapid growth during the sapling and pole stages to crop trees. All trees would now be merchantable with large crowns and stem form adequate to resist windthrow and snow or ice damage. For example, in a 33-year-old larch stand in eastern Oregon (site index 80) (Seidel 1971), volume growth after thinning to 50 ft^2 per acre (11.5 m^2/ha) was 86 ft^3 per acre (6 m^3/ha) per year compared with an annual growth rate in this 55-year-old stand of 48 ft^3 per acre (3.4 m^3/ha) when thinned from below to the same density level.

Because of its shade intolerance and the tendency of many natural stands to be heavily overstocked, larch is a species in which early thinning should have high priority. Studies in Montana show that diameter and height growth of unthinned stands were significantly decreased by overstocking as early as 9 years of age (Schmidt 1966). Although mortality reduces stocking as stands grow older, many spindly trees with small crowns survive. These trees show little or no growth response to thinning and are most susceptible to wind damage.

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